Response of RC Structure under Random Vibration

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Abstract— In this Paper, Time history analysis is analyzed for the modelled structure due to random vibration. MATLAB coding is developed for determining the response i.e. mean peak acceleration of the structure. The probability of peak acceleration is determined. For the determined values of the structure, base shear is calculated for each cases. In this paper aims to determine the response of the structure. When random vibration is given, the response of the structure is determined using MATLAB. By giving el-Centro data as input, time history analysis is determined. Time history analysis is calculated for random signal, sinusoidal signal and loading case.

Key words: Random Vibration, El Centro Earthquake, Sinusoidal loading, Repated loading, Peak Ground Acceleration

I. Introduction

The important objective of earthquake engineers is to design and build a structure in such a way that damage to the structure and its structural component during the earthquake is minimized. This report aims towards the dynamic analysis of a multi-storey RCC building with symmetrical configuration. For the analysis purpose model of seven storeys RCC with symmetrical floor plan is considered. The analysis is carried by using finite element based software SAP 2000.

Various response parameters such as lateral force, base shear, story drift, story shear can be determined. For dynamic analysis time history method can be used. Time-history analysis may be an in small stages analysis of the dynamic response of a structure to a loading which will vary with time.

The analysis may be linear or non-linear. Dynamic analysis may be performed for symmetrical further as unsymmetrical building. Dynamic analysis can be in the form of nonlinear dynamic time history analysis.

There is high demand for construction of tall buildings because of increasing urbanization and helical population, and earthquakes have the potential for causing the greatest damages to those tall structures. Since earthquake forces area unit random in nature and unpredictable, the engineering tools need to be sharpened for analyzing structures under the action of these forces. Earthquake loads are required to be carefully modeled so as to assess the real behavior of structure with a clear understanding that damage is expected but it should be regulated.

In this paper, a nonlinear time history analysis is performed on a seven storey RCC building frame considering time history of El Centro earthquake 1940 using SAP 2000. From the study it is recommended that analysis of multi-storeyed RCC building using time history method becomes necessary to ensure safety against earthquake force.

The main parameters of the seismal analysis of structures area unit load carrying capability, ductility, and stiffness, damping and mass. The various response parameters like base shear, storey drift, storey displacements etc. are calculated.

The damages are caused by inconsistence seismic response, irregularity in mass and plan, soft storey and floating columns etc. Hence it becomes necessary to guage actual seismic performance of building subjected to earthquake forces.

The dynamic analysis of structures subjected to excitations which were known as a function of time. Such an analysis is said to be deterministic. When an excitation function applied to a structure has an irregular shape that is described indirectly by statistical means, we speak of a random vibration. Such a function is usually described as a continuous or discrete function of the exciting frequencies, in a manner similar to the description of a function by Fourier series.

In structural dynamics, the random excitations most often encountered are either motion transmitted through the foundation or acoustic pressure. Both of these types of loading are usually generated by explosions occurring in the vicinity of the structure.

Common sources of these explosions are construction work and mining. Other types of loading, such as earthquake excitation, may also be considered a random function of time. In these cases, the structural response is obtained in probabilistic terms using random vibration theory.

A record of random vibration is a time function such as shown in figure 1. The main characteristic of such a random function is that its instantaneous value cannot be predicted in a deterministic sense.

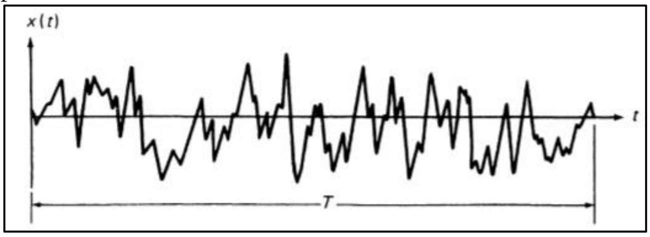

Fig. 1: Random Vibration

The description and analysis or random processes are established in a probabilistic sense for which it is necessary to use tools provided by the theory of statistics.

Time History analysis gives more realistic seismic behavior of the building. It gives more accurately seismic responses than response spectrum analysis because of it incorporates material nonlinearity and dynamic nature of earthquake.

The building under consideration is modeled with the help of SAP2000 software. The software system is ready to predict the geometric nonlinear behavior of space frames below static or dynamic loadings, taking into account both geometric nonlinearity and material inelasticity.

The values of seismic responses specifically base shear, storey displacement and storey drifts for all the Time Histories. It is counseled that analysis of multistory RCC building mistreatment Time History technique becomes necessary to make sure safety against earthquake force. It provides a higher check to the security of structures analyzed and designed.

II. LITERATURE REVIEW

A.S. PATIL & P.D. KUMBHAR, In the present paper study of nonlinear dynamic analysis of Ten storied RCC building considering different seismic intensities is carried out and seismic responses of such building are studied. The building under consideration is modelled with the help of SAP2000-15 software. Five totally different time histories are used considering unstable intensities V, VI, VII, VIII, IX and X on changed Mercalli's Intensity scale (MMI) for institution of relationship between unstable intensities and seismic responses. The results of the study show similar variations pattern in Seismic responses such as base shear and storey displacements with intensities V to X. From the study it is recommended that analysis of multi-storeyed RCC building using Time History method becomes necessary to ensure safety against earthquake force.

AKIL AHMED, this report aims towards the dynamic analysis of a multi-storey RCC building with symmetrical configuration. For the analysis purpose model of 10 storeys RCC with symmetrical architectural plan is taken into account. The analysis is carried by using finite element based software SAP 2000. Various response parameters like lateral force, base shear, story drift, story shear can be determined. In this paper, a nonlinear time history analysis is performed on a 10 story RCC building frame considering time history of El Centro earthquake 1940 mistreatment SAP 2000. The main parameters of the unstable analysis of structures ar load carrying capability, ductility, stiffness, damping and mass. The various response parameters like base shear, storey drift, storey displacements etc. are calculated. The storey drift calculated is compared with the minimum requirement of storey drift as per IS 1893:2002.

ISSAM ABU-MAHFOUZ & AMIT BANERJEE, this work demonstrates crack detection and identification of different lengths are introduced at three different locations along a cantilevered steel beam. The objective is to correlate crack length and crack propagation to the statistical moments, frequency spectra and wavelet coefficient data. The objective of the present paper is to investigate the application of the fuzzy clustering method using experimentally obtained vibration response data to predict the location of cracks in a cantilever beam.

MALAY QUILA, PROF. SAMAR CH. MONDAL & PROF. SUSENJIT SARKAR, This paper focuses on the theoretical analysis of transverse vibration of a fixed beam and investigates the mode shape frequency. Co relate the theoretical values with the numerical values to search out proportion error between them. Variations of natural frequencies thanks to crack at numerous locations and with variable crack depths are studied. The natural frequency changes considerably thanks to the presence of cracks relying upon location and size of cracks. Crack positions are constant; the natural frequencies of a cracked beam are inversely proportional to the crack depth. Change in frequencies isn't solely perform of crack depth, and crack location, but also of the mode number.

N.T. KHIEMA & T.V. LIEN, Multi-crack detection for beam by natural frequencies has been developed within the variety of a non-linear optimisation drawback, then solved by using the MATLAB. The aim is to develop the dynamic stiffness matrix approach to crack detection in structures. The focus of this paper is mainly on the problem of multi-crack detection for one-dimensional structures by natural frequencies. In the present paper, the DSM model has been successfully applied to detect numerous cracks in beams by natural frequencies. The more natural frequencies are measured the more accurate is the crack position detected.

PENG LIPING & LIU CHUSHENG, the vibration property of a rectangular-hollow-sectional beam with an external crack were theoretically and experimentally studied in this paper. The transfer matrix method was introduced to obtain the frequency equations of these cracked beams under three classic boundary conditions and followed by the numerical method for calculating natural frequencies. It should be noted that a part-through crack may lead to a more natural frequency reduction than the through-thickness crack.

ROMY MOHAN & C PRABHA, in this, two multi storey buildings, one of six and other of eleven storey have been modelled using software package SAP 2000 12 for earthquake zone V in India. Six different types of shear wall with its variation in shape are considered for studying their effectiveness in resisting lateral forces. The paper conjointly deals with the result of the variation of the building height on the structural response of the shear wall. Dynamic responses below distinguished earthquake, El-Centro have been investigated. This paper highlights the accuracy and accuracy of your time History analysis compared with the foremost unremarkably adopted Response spectrographic analysis and Equivalent Static Analysis.

S. LOUTRIDIS, E. DOUKA & A. TROCHIDIS, in this method for crack identification in double-cracked beams based on wavelet analysis is presented. The fundamental vibration mode of a double-cracked cantilever beam is analyzed mistreatment continuous riffle rework and each the situation and depth of the cracks ar calculable. The location of the cracks is determined by the sudden changes in the spatial variation of the transformed response. To estimate the relative depth of the cracks, an intensity factor is established which relates the size of the cracks to the coefficients of the wavelet transform. It is shown that the intensity factor follows definite trends and therefore can be used as an indicator for crack size. The projected technique is valid each analytically and by experimentation just in case of a double-cracked cantilever beam having cracks of variable depth at totally different positions. In the light of the obtained results, the advantages and limitations of the method are presented and discussed. For the estimation of the relative depth of the cracks an intensity factor was established. It relates the size of the cracks to the corresponding wavelet coefficients. It was shown that the intensity factor changes with crack depth according to a second order polynomial law and therefore, can be used as an indicator for crack extent.

X.PITOISET, I. RYCHLIK & A. PREUMONT, this paper proposes computationally efficient frequency domain formulations for two well-known multiaxial fatigue failure criteria, namely Matake's critical plane criterion and Crossland's criterion. For that purpose, it is shown how fatigue-related variables involved in both criteria can be estimated from the power spectral density matrix of the local stress vector. The finite element model of an example structure is then used to illustrate the application of the proposed frequency domain approaches. It is observed that both frequency domain formulations produce consistent results when compared with those obtained in the time domain from Monte-Carlo simulations of local stress vectors while offering tremendous computer savings. A frequency domain tool indicating whether the principal stress directions do rotate with time or not during the loading at a given location in the structure is also presented.

YAMUNA.P & K. SAMBASIVARAO, the objective of this study is to analyze the vibration behavior of a simply supported beam using FEM software ANSYS subjected to a single triangular crack under free vibration. They determined the natural frequencies and mode shape. The beam model with a triangular crack located initially at 50 mm, and then the crack locations are varied at 50 mm to 450mm. For crack position at 50 mm the lowest frequency is 230.74 Hz and for crack position at 450 mm the lowest frequency is 230.68 Hz which is almost equal. The dynamic response of crack at symmetric locations of the beam is similar.

III. RESULT & DISCUSSION

A. *Response Due To Random Vibration*

To determine the response of a structural system subjected to a random excitation, we need to examine the frequency content of the excitation function. We are mostly interested in estimating the spectral function or the spectral density function of the excitation. If a random process x(t) is normalized (or adjusted) so that the mean value of the process is zero, then, provided that x(t) has no periodic components, the autocorrelation function Rx(τ) approaches zero as r increases.

The el-Centro data is processed in MATLAB and obtaining a graph which contains acceleration versus time. This el-Centro data is obtained for the year 1940. By using this data, power spectral density is obtained. By taking the peak value, the mean square of the response is calculated and the probability is also calculated.

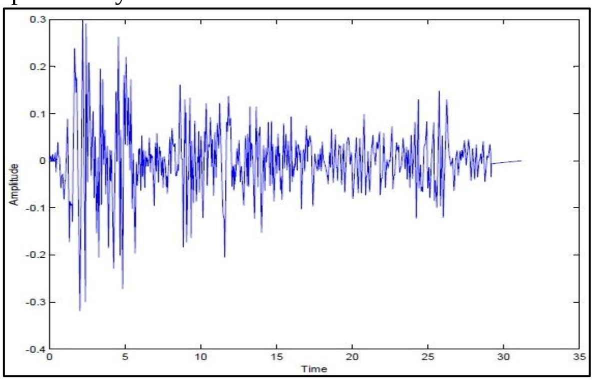

Fig. 2: Earthquake Data

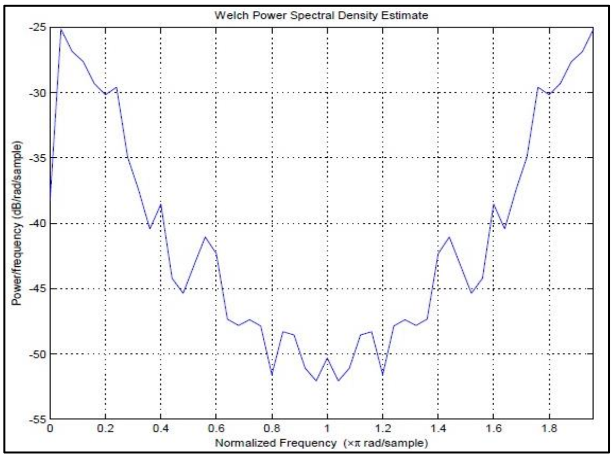

Fig. 3: Power Spectral Density

For response calculation,

F_n	ΔF_n	$S(F_n)$	$\lvert H_n \rvert$	A_p^2
0	0.1	0	0.5	0
0.1	0.1	0.25	1	0.025
0.2	0.1	0.302	1.4	0.059
0.3	0.1	0.370	4	0.592
0.4	0.1	0.38	1.2	0.055
0.5	0.1	0.43	1.7	0.124
0.6	0.1	0.41	2.7	0.807
0.7	0.1	0.46	1.8	0.149
0.8	0.1	0.52	2.7	0.379
0.9	0.1	0.52	2.3	0.275
1	0.1	0.51	2.8	0.399

Table 1: Response Calculation

The mean square value of the response ,

$$A_p^{\,2} = 2.86\ g^2$$

$$\sigma = (2.86\ g^2)^{0.5}$$

$$= 1.692g$$

The probability of exceeding specified accelerations can now be found assuming the normal distribution as,

$$P[|A_p| > 1.692g] = 31.7\%$$

and

$$P[|A_p| > 5.076g] = 0.3\%$$

Similarly, the probability that the peak acceleration Ap at point P will exceed a specified value is found using the Rayleigh distribution as,

$$P[|A_p| > 1.692g] = 60.65\%$$

and

$$P[|A_p| > 5.076g] = 1.11\%$$

The value of mean square of the response, $a_p^2 = 2.864g^2$. The variance is calculated as 1.692g. The probability of exceeding specified accelerations can be found using normal distribution as 31.7%. The probability of exceeding specified acceleration can be found using Rayleigh distribution as 60.65%.

B. *Structural Modelling & Analysis*

The finite element analysis software SAP 2000 Nonlinear is utilized to create 3D model and run all analyses. The software is able to predict the geometric nonlinear behavior of space frames under static or dynamic loadings, taking into account both geometric nonlinearity and material inelasticity.

In this report, a nonlinear time history analysis will be performed on a seven storey RCC building frame considering time history of El Centro earthquake 1940.

It is recommended that time history analysis should be performed as it predicts the structural response more accurately than the response spectrum analysis. The structure is subjected to random vibration, sinusoidal wave and impulse loading. For all the cases, base reactions, joint displacement, element force and joint force are calculated.

Seven storey building is modelled and analyzed in sap 2000 software. For the analysis purpose basic parameter taken are lateral force, base shear, storey drift, storey shear and results are interpreted.

The size of beam is chosen as 0.25m X 0.35m. The size of column is chosen as 0.4m X 0.2m. the slab thickness of 0.15m.

- The modelled structure is shown in Figure 4.
- Live Load on Typical floors - 3.5 KN/m^2
- Live Load on Terrace - 2 KN/m^2
- Brick wall Thickness -0.230 m
- Density of Concrete - 25 KN/m^2
- Density of Brick wall - 20 N/m^2
- Modulus of Elasticity for Concrete - 25 KN/m^2
- Modulus of Elasticity for Brick wall - 10.5 KN/m^2

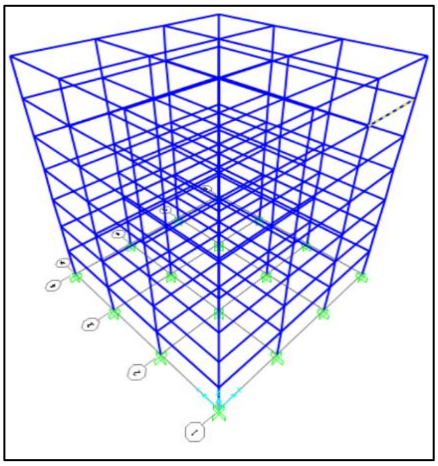

Fig. 4: Modelled Structure

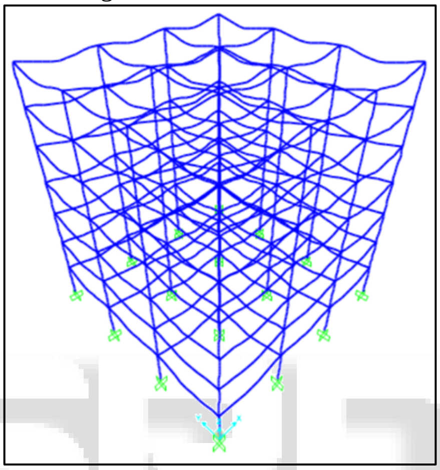

Fig. 5: Deformed Structure

C. Time History Analysis & Random Vibration

Base Reactions								
Output Case	Case Type	Step Type	Global FX	Global FY	Global FZ	Global MX	Global MY	Global MZ
			KN	KN	KN	KN-m	KN-m	KN-m
time history	NonDirHist	Max	2497.728	4.798E-13	0.004364	0.0393	35331.0064	24345.8317
time history	NonDirHist	Min	-2705.092	-4.089E-13	-0.004384	-0.0395	-32855.1478	-22479.5493
dead+ time	Combination	Max	2497.728	4.8E-13	2578.043	23202.3857	12128.6599	24345.8317
dead+time	Combination	-22479.5	-22479.55	-22479.549	-22479.55	-22479.549	-22479.5493	-22479.5493

Table 2: Base Shear for Time History Analysis for Random Vibration

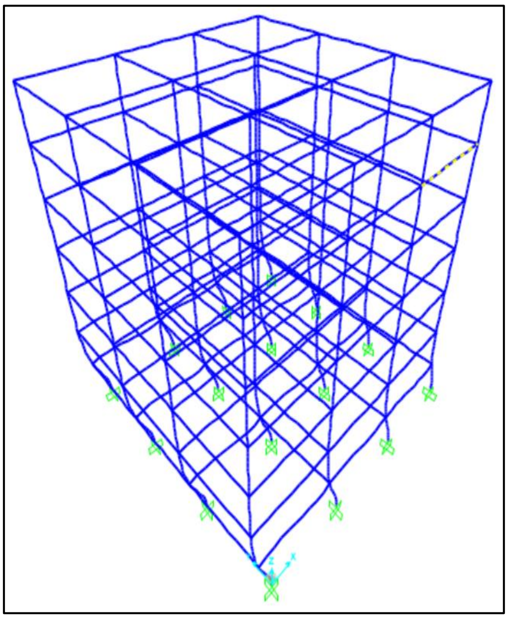
Fig. 6: Deformed Shape Due to Random Vibration

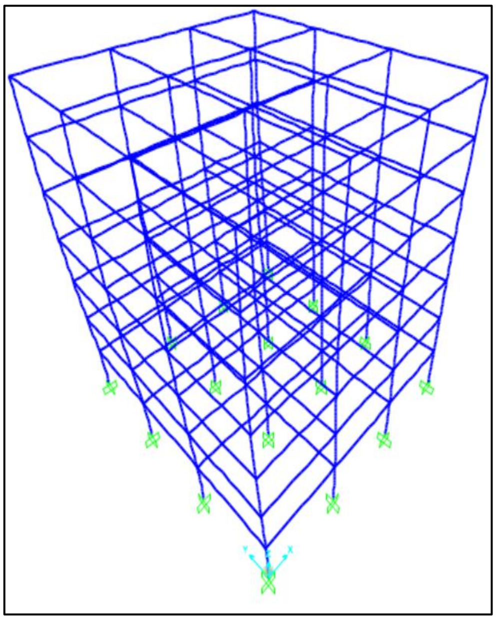
Fig. 7: Deformed Shape under Sinusoidal Signal

Base Reactions							
Output Case	Case Type	Global FX	Global FY	Global FZ	Global MX	Global MY	Global MZ
Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
COMB1	Combination	278.3	-2.764E-14	2729.194	24562.7446	-21351.5871	-2504.7029

Table 3: Base Shear Due to Sinusoidal & Dead Load

Base Reactions							
Output Case	Case Type	Global FX	Global FY	Global FZ	Global MX	Global MY	Global MZ
Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
DEAD	LinStatic	6.661E-16	-1.11E-15	2729.194	24562.7446	-24562.7446	-2.842E-14

Table 4: base Shear Due to Dead Load

Base Reactions							
Output Case	Case Type	Global FX	Global FY	Global FZ	Global MX	Global MY	Global MZ
		KN	KN	KN	KN-m	KN-m	KN-m
SINE	LinStatic	278.3	-2.653E-14	-2.132E-14	-5.842E-13	3211.1575	-2504.7029

Table 5: Base Shear Due to Sinusoidal signal

D. Base Shear for Load Case (Manual Random Vibration as Load)

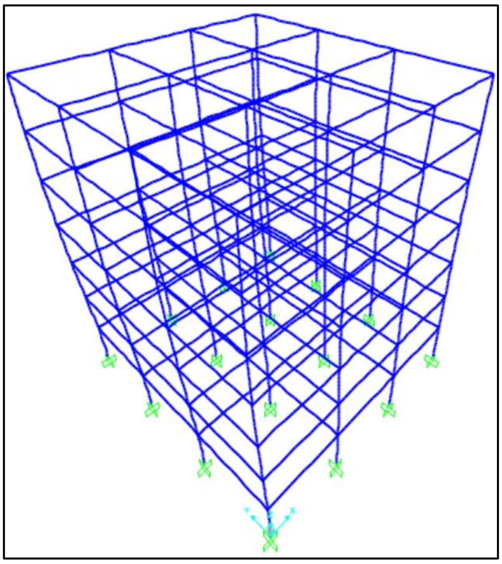
Fig. 8: Deformed Shape Due to Load Case

Time	Acceleration
0	0
1	0.02
2	0.04
3	0.06
4	0.08
5	0.1
6	0.12
7	0.14
8	0.16
9	0.18
10	0.2
11	0.22
12	0.24
13	0.26
14	0.28
15	0.3
16	0.32
17	0.34
18	0.36
19	0.38
20	0.4
21	0.42
22	0.44
23	0.46

24	0.48
25	0.5
26	0.52
27	0.54
28	0.56
29	0.58
30	0.6
31	0.62

Table 6: Manual Random vibration

Base Reactions							
OutputCase	CaseType	GlobalFX	GlobalFY	GlobalFZ	GlobalMX	GlobalMY	GlobalMZ
		KN	KN	KN	KN-m	KN-m	KN-m
COMB1	Combination	278.3	-2.909E-14	2729.194	24562.7446	-21351.5871	-2504.7029

Table 7: Base Shear for Load Case

IV. CONCLUSION

In this Paper, base shear, joint displacement, joint reaction and storey drift for the structure is determined under the conditions of random vibration, sinusoidal signal and load case. MATLAB coding is developed for determining the response i.e. mean peak acceleration of the structure. For the determined values of the structure, base shear is calculated for each cases.

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